February 7, 2013
A. Shemyakin

Nominal PXIE MEBT bunch structure scenarios

The PXIE [1]warm front end will operate in various modes differing by the bunch structures. This paper suggests selecting several representative scenarios, for which the requirements for diagnostics will be specified.

Definitions:

Periodicity: 256 RF 162.5 MHz buckets (period ≡ 1575 ns)
Bunch: Filled 162.5 MHz bucket
Batch: continuous train of bunches

Mode 1. Nominal operating mode ("CW")

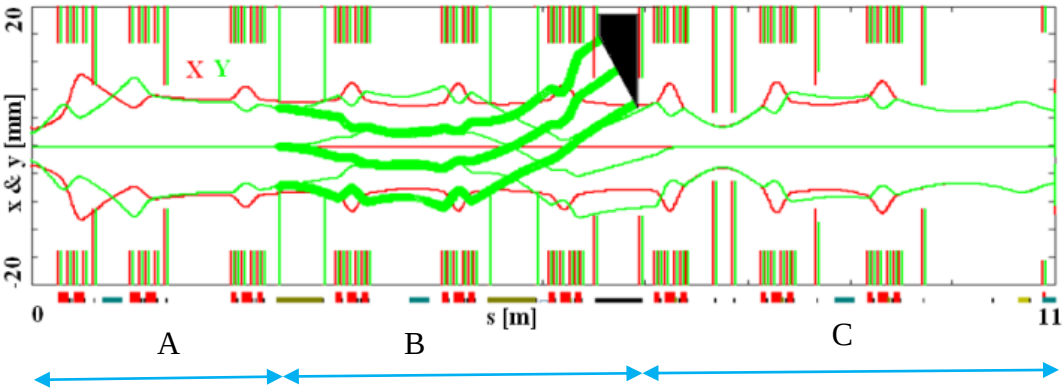

Figure 1: Scheme of MEBT optics [2]and the beam envelope. The thin lines are the central trajectory and 3σ envelope (ε_{rms_n}=0.25 mm mrad) of the passing beam, and the thick lines are the Y envelope of the chopped-out beam. Red- quadrupoles, blue- bunching cavities. BPMs are inside of each doublet or triplet.

In the operating mode, the beam has different structures in three spacial regions as depicted in Figure 1:

A) Beam from RFQ exit to 3rd BPM (M02B): CW§ 162.5 MHz, 5 mA average current

B) In the middle, from the BPMs M03B to M05B, all buckets are filled but the bunches scheduled to be removed and passed have different vertical offsets.

C) The beam is chopped to create the following structure at the MEBT exit (starting from the 7th BPM, M06B) as shown in Figure 1Figure 2:
Periodicity- 256 RF buckets (1,575 ns), average current of 1 mA

Each period contains:

- 12 bunches in buckets 1, 3, …23 (i.e. ~ 140 ns train of bunches at 81.25 MHz, representing "muon pulses")

- 25 bunches in buckets 2, 10, … 194 (20.3 MHz, “kaon pulses”)
- 13 bunches in buckets 4, 20, … 196 (10.15 MHz, “nuclear pulses”)
- All other buckets empty.

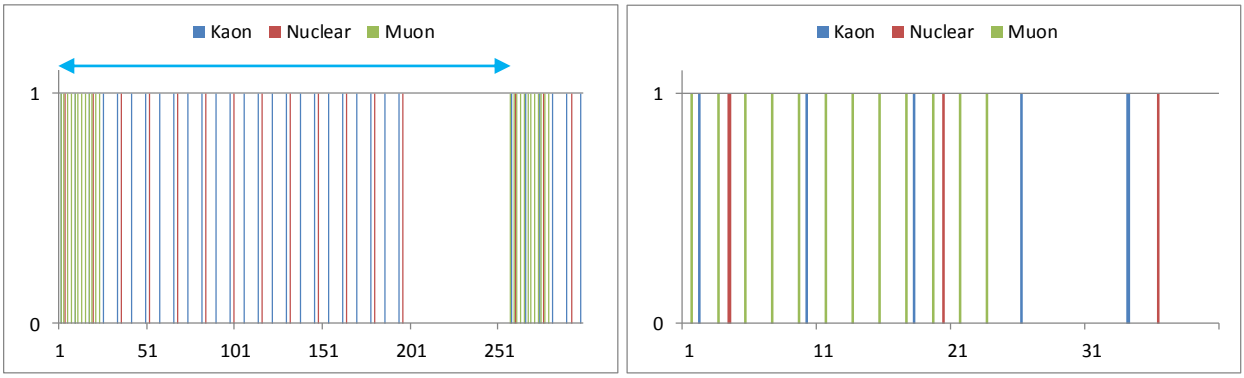

Figure 2: The bunch structure at the exit of MEBT in the nominal operating mode. Left: the arrow indicate the full period. Right: details of the beginning of the period with “muon” pulses. The horizontal axis is numbered according to the bucket number.

Operation in this mode can be started, stopped, or interrupted by the Machine Protection System using the LEBT chopping system (see Mode 5).

§ The bunch sequence is interrupted for 1 period (1.575 μs) every 1000 periods (1.575 ms) by the LEBT chopping system for ion clearing in MEBT.

Mode 2. Pulse mode

The beam is chopped in LEBT for commissioning and diagnostics purposes.

Peak current in LEBT -	5 mA
Frequency of batches -	60 Hz
Rise and drop times of intensity in the batch§ -	~100 ns
Flat top -	15.75 μs (10 periods)

The MEBT kickers can be either on or off, with the corresponding difference of trajectories as in Mode 1.

§ Transverse position of partly removed bunches may differ ~1 mm from those at the flat top.

Mode 3. Pre-chopped CW

The beam is pre-chopped in the LEBT to the nominal average current of 1mA. The mode can be used for the thermal test of the MEBT absorber, preliminary tests of SRF, or together with MEBT chopping system in a case of temporary limitations on the duty factor of the latter.

Peak current in LEBT -	5 mA
Frequency of batches -	635 kHz
Rise and drop times of intensity in the batch§ -	~100 ns

Flat top - 0.2 μs

[§] Transverse position of partly removed bunches may differ ~1 mm from those at the flat top.

Mode 4. Synchronous detection in CW mode

Identical to Mode 1 but bunch parameters (either the transverse position or intensity) are slightly modulated at ~100 Hz. Typical transverse shift is ~0.1 mm, and typical amplitude modulation is $\sim 10^{-5}$. The mode is used for non-invasive diagnostics.

Mode 5. Beam interruption

The beam is interrupted by the LEBT chopping system, so that no beam is injected into the RFQ and further downstream. The system is capable to stay indefinitely in this mode.

Acknowledgment

I am thankful to B. Chase, V. Lebedev, L. Prost, and J. Steimel for discussions, comments, and suggestions.

References

[1] S. Nagaitsev et al, "PXIE: Project X Injector Experiment," in *Proc. of IPAC'12*, New Orleans, USA, 2012, THPPP058.

[2] V. Vebedev et al, "PXIE Optics and Layout," in *Proc. of IPAC'12*, New Orleans, USA, 2012, THPPP057.